

Creep Life Estimation of Low Pressure Reaction Turbine Blade

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Abstract Steam turbine blades are the most important component of the thermal power plant. Most of the research work on creep estimation is done on the high pressure or intermediate pressure turbines blades. The main aim of this study is to estimate the creep life of 210 MW low pressure steam turbine blade. In first stage the three dimensional model of the blade was prepared in the PRO-E then this model is imported in ANSYS-14.5 for finite element analysis. Maximum stress and maximum deformation can be obtained using finite element analysis then by using modified Larson miller parameter method the creep life of the turbine blade can be estimated.

Keywords: *Creep; Larson Miller Parameter; Stress Analysis ; Turbines.*

I. INTRODUCTION

Steam turbines are the main prime movers in thermal power stations. The main parts of steam turbine are rotor, blades and nozzles. Turbine blades are having various loads such as thermal, inertia and bending and may fail due to different factors like low cycle fatigue, high cycle fatigue, temperature creep rupture and corrosion etc. [1]. These turbine blades are working under very high temperature and various mechanical loadings depended basically on time which will cause the deformation and fracture of steam turbine blade. Hence for turbine blade the material should have capability of tolerating high stress and temperatures for long period of time [2]. Mostly the Nickel-based super alloys can use for turbine blade because they can tolerate high temperature and stresses for long period of time we are using one of the most important Ni-based super alloy IN738LC.

We are using this material because it is corrosion resistance and also creep resistance in high temperature. Turbine blade is generally made of Ni-based super alloy. Basically are two important carbide in this super alloy MC, M₂₃C₆, being long time under high temperatures, the grain boundaries of M₂₃C₆ carbide leads continuous layer of carbide covers the area. This event leads to a high decrease creep resistance of blade [2].

As we all know that there is wide range of software which is useful in drawing models and different types of analysis can also perform on these software. In this study

first of all the model of the turbine blade is prepared in the PRO-E software by using the dimensions and co-ordinate of the blade then this model is imported in ANSYS-14.5 for finite element analysis (FEA), here the stress analysis is perform on the turbine blade by using mechanical properties of the material and operating condition i.e. pressure, temperature and load etc. Afterwards the creep life estimation of the turbine blade is calculated by using Modified Larson Miller Parameter method subsequently the deformation of the gas turbine blade is evaluated and results are shown.

II. PROBLEM DEFINITION

Most of the thermal power plants use impulse-reaction or reheat-reaction turbines because their blading efficiency is higher than the impulse turbines [3]. We know that these turbine blades work on very high temperature and loads. In this work we will calculate the maximum stress and maximum deformation on the root of the last stage low pressure large steam turbine blade rotating at 3000 rpm. Thermal stress analysis is perform using ANSYS-14.5 then by using modified Larson Miller Parameter creep life of the blade can be calculated.

III. OBJECTIVES

- To calculate the maximum stress on low pressure steam turbine blade.
- To calculate the maximum deformation on the low pressure steam turbine blade.
- To calculate creep life of the turbine blade using Modified Larson Miller Parameter.
- To calculate the effect of changing temperature on the creep life of steam turbine blade.

IV. RESEARCH METHODOLOGY

The methodology used in this work to carry out creep analysis of 210 MW low pressure blade of steam turbine rotating at 3000 rpm is-

- Model of the steam turbine blade is prepared in PRO-E software.

- Model is imported in the ANSYS-14.5 to calculate Stress distribution on turbine blade and root.
- ANSYS-14.5 software is used to calculate the maximum stress and maximum deformation on the steam turbine blade by using boundary conditions.
- Larson Miller Parameter is used to calculate creep life of turbine blade.

V. COMPOSITION AND PROPERTIES OF STEAM TURBINE BLADE

Modern turbine blades often use Nickel based super alloy that incorporate chromium, cobalt, rhenium.[4] Steam turbine blades are generally made up of Ni-based super alloy because this alloy has the capacity to resist high temperature and stress for a long period of time. Chemical composition of this material is shown in table 1.

TABLE I. CHEMICAL COMPOSITION OF BLADE[5]

| Alloy | C | Cr | Ni | Co | Mo | W |
|---------|------|-----|-----|------|------|------|
| IN738LC | 0.11 | 16 | Bal | 8.5 | 1.75 | 2.6 |
| Alloy | Cb | Ti | Al | B | Zr | Ta |
| IN738LC | 0.9 | 3.4 | 3.4 | 0.01 | 0.06 | 1.75 |

The various mechanical properties of the material IN738LC like young's modulus, poisson's ratio etc. are given in the table below which is useful in the stress analysis of the turbine blade.

TABLE II. MATERIAL PROPERTIES OF IN738LC [6]

| Mechanical properties | Sign | Value |
|--------------------------------|------|--------------------------------------|
| Young's modulus | E | 175 Gpa |
| Thermal expansion coefficient | A | $11.6 \times 10^{-6} \text{ K}^{-1}$ |
| Poisson's ratio | T | 0.3 |
| Density | P | 8110 kg/m^3 |
| Thermal conduction coefficient | K | 18 W/mK |

TABLE III. OPERATING PARAMETERS OF TURBINE BLADE

| | | |
|---|----------------|----------|
| 1 | Temperature | 535°C |
| 2 | Rated Speed | 3000 rpm |
| 3 | Rated capacity | 210 MW |

VI. FINITE ELEMENT MODEL OF THE LOW PRESSURE TURBINE BLADE

Figure 1 and Figure 2 shows the different view of geometric model of steam turbine blade.

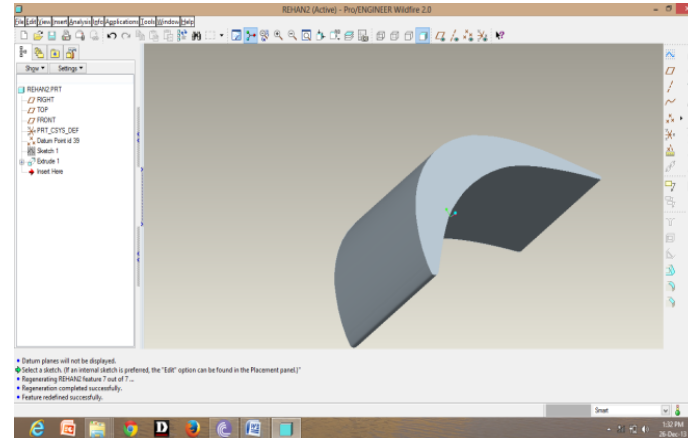


Figure 1. Geometric model of turbine blade

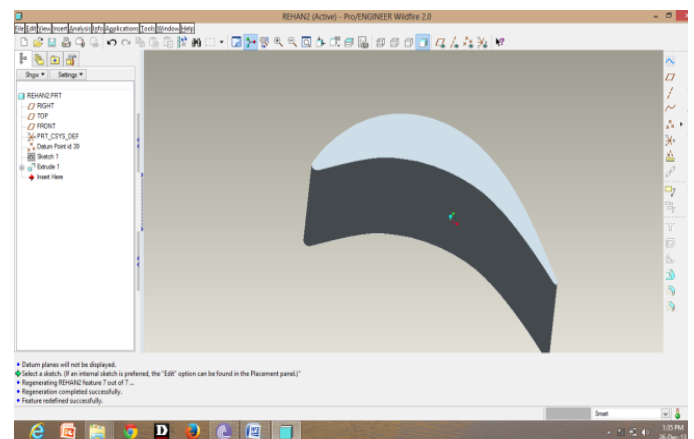


Figure 2. Another view of turbine blade

The geometric model of 210 MW reheat reaction turbine blade is generated by using the co-ordinates and dimensions of the turbine blade. The software used to prepare this geometric model is PRO-E. After applying the forces and displacement condition in the blade, von misses stress value of the steam turbine blade was calculated with the help of ANSYS-14.5 software.

VII. 3- DIMENSIONAL STRESS ANALYSIS

The purpose of finite element analysis is to recreate mathematically the behavior of an actual engineering system. In other words, Analysis must be an accurate mathematical model of a physical prototype [7]. In order to 3-D Analysis stress in gas turbine blade we are required information such as geometric model, boundary conditions, loading and material properties. In general four main sources of stress in steam turbine blades includes centrifugal stresses strength, bending stress due to gas pressure, centrifugal bending stress and thermal stresses resulting from working in high temperatures. Comparing with the other three sources thermal stress is less and insignificant. Therefore we will calculate the other three stresses [8].

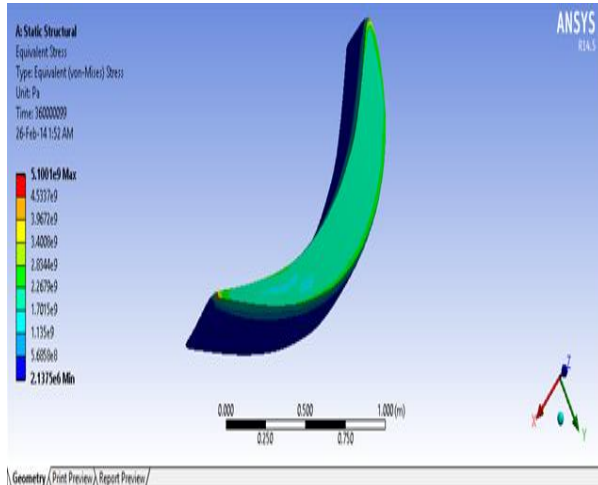


Figure 3. Von Mises stress distribution

From figure 3 we can see the maximum stress at root of the blade is 510 Mpa.

VIII. MODIFIED LARSON MILLER PARAMETER

Larson Miller Parameter is useful for creep life prediction. The Larson Miller parameter can be used for designing in order to achieve maximum working condition as well as to attain favorable function lifetime. This method also presented the correlation between stress, Temperature and fracture time. In figure 4 the relationship between stress and Larson miller parameter is plotted [2].

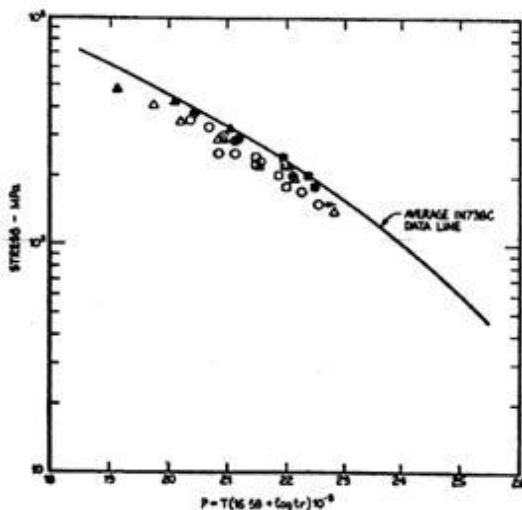


Figure 4. Relationship between stress and Larson Miller Parameter[2]

The modified Larson Miller Parameter can be defined as [2]:-

$$LMP = T [\log_{10} t + C] \times 10^{-3}$$

T=Temperature in Kelvin

σ = Stress in Pascal

t = Creep life in hours

C= Constant for IN738LC considered 20 for 100000 hours

As it is shown in figure. 4 that when the value of stress is 510 Mpa the value of Larson Miller Parameter is 19.25 Operating temperature of steam is 808 K.

Now putting all the values in the Modified Larson Miller Parameter Equation the equation can be written as

$$19.25 \times 10^{-3} = 808 [\log_{10} t + 20]$$

$$\log_{10} t = 3.824$$

$$t = 6668.04 \text{ hrs}$$

Now from the above result we can say that when the component is operated at 3000 rpm and at 808 K temperature, it can be safely operated upto 6668.04 hrs if the phenomenon of creep is considered.

IX. RESULTS AND DISCUSSION

In this study, first of all the model of the turbine blade is prepared according to the co-ordinates given then the 3-D stress analysis is performed on the blade from which the maximum stress is equal to 510 Mpa is calculated. Then Larson Miller Parameter is used because of its correctness to calculate the creep life at the operating condition given. The result shows that in the operating condition the creep life is 6778.04 hours.

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